

# Nerves of the Lower Extremity

## Introduction

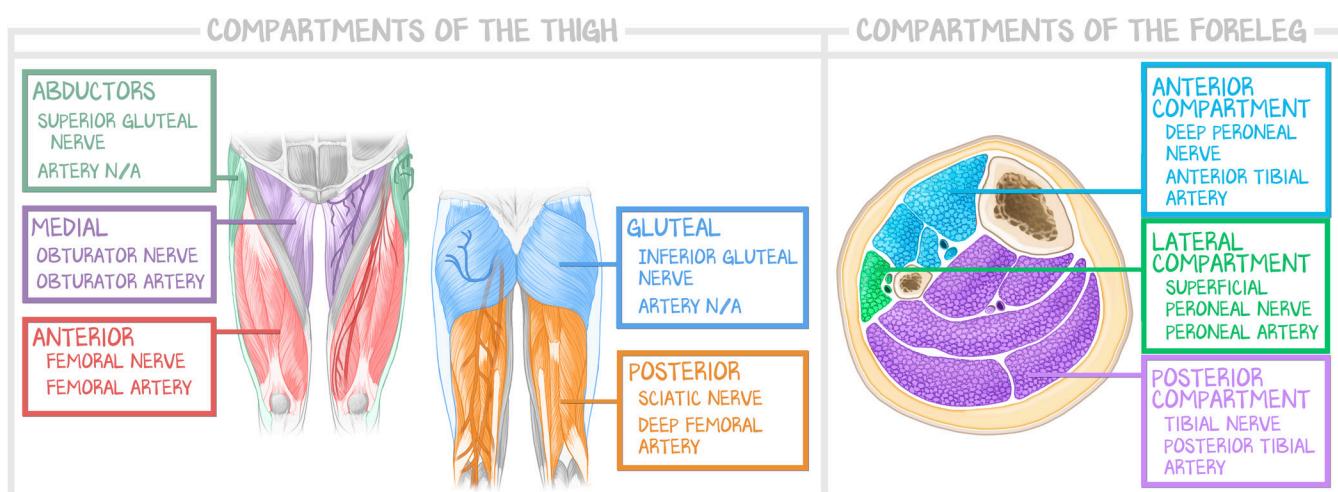
In MSK #4: *Anatomy of the Lower Extremity*, we paired each muscular compartment with an artery and a motor nerve. We're now going to do that again briefly, then spend a lot of time on the sensory innervation of the lower extremity. In MSK #3: *Nerves of the Upper Extremity*, we explored the brachial plexus in detail. In this lesson, however, we are not going to construct, trace, or memorize anything regarding the brachial plexus or lumbar plexus. In fact, we're just going to refer to both plexuses as a single lumbosacral plexus, the nerves of the lower extremity.

This lesson is about nerves, but we start with the muscles and the compartments they innervate. We then explain the dermatome with a twist (you'll see what we mean in a few paragraphs), then break down the leg into three regions of terminal nerve sensory innervation. The goal here is to learn the leg in a manageable way. Unlike the upper extremity, which is relatively easy compared to the leg, the lower extremity is a plethora of nerves and mechanisms of nerve lesions. We'll close with lumbar radiculopathy.

## Using the Muscles to Explore the Nerves (A Review)

**Level of the pelvis.** There is the **gluteal compartment** (gluteus maximus: hip extension) that is innervated by the inferior gluteal nerve (L5–S2) and the **abductor compartment** (the other gluteus muscles: adduction, internal rotation, and stabilization of locomotion) that is innervated by the superior gluteal nerve (L4–S1). The deep muscles of the hip, the ones that do external rotation, are not worth memorizing and have no nerve associated with them.

**Level of the thigh.** At the level of the thigh there are three compartments. The **anterior compartment** (flex hip, extend knee) is irrigated by the femoral artery and innervated by the femoral nerve (L2–L4). The **medial compartment** (the adductors) is irrigated by the obturator artery and the obturator nerve (L2–L4). The **posterior compartment** (extend hip, flex knee) is irrigated by the deep femoral artery and innervated by the proximal sciatic nerve (L4–S3). The sciatic nerve branches into multiple different nerves in the foreleg and foot.



**Figure 6.1: Compartments**

This review of the anatomy will orient you to the function of each compartment, separated into the gluteal region, thigh region, and foreleg region. The goal is to bridge what you already know to what you need to learn.

**Level of the foreleg.** In the foreleg, there are also three compartments. The **anterior compartment** (dorsiflexion of foot, inversion at ankle) is irrigated by the **anterior tibial artery** but innervated by the **deep peroneal nerve**. The **lateral compartment** (eversion of foot) is the fibular muscles, also known as peroneal; this compartment is irrigated by the peroneal artery and innervated the **superficial peroneal nerve**. The **posterior compartment** (plantarflexion, inversion at ankle) is irrigated by the **posterior tibial artery** but innervated by the **tibial nerve**.

LOCATION	COMPARTMENT	ACTION	ARTERY	NERVE
Gluteal	Gluteal	Extend hip	N/A	Superior gluteal (L4-S1)
Gluteal	Abductors	Abduct hip	N/A	Inferior gluteal (L5-S2)
Thigh	Anterior	Flex hip, extend knee	Femoral	Femoral (L2-L4)
Thigh	Medial	Adduct hip	Obturator	Obturator (L2-L4)
Thigh	Posterior	Ext Hip, flex knee	Deep femoral	Sciatic (L4-S3)
Foreleg	Anterior	Dorsiflex foot Invert ankle	Anterior tibial	Deep peroneal (sciatic branch)
Foreleg	Posterior	Plantarflex foot Invert ankle	Posterior tibial	Tibial (sciatic branch)
Foreleg	Lateral	Evert ankle	Superficial peroneal	Superficial peroneal (sciatic branch)

**Table 6.1: Compartment Review with Nerves**

Categorization and orientation of previously learned knowledge (the compartments), now with the nerves added on.

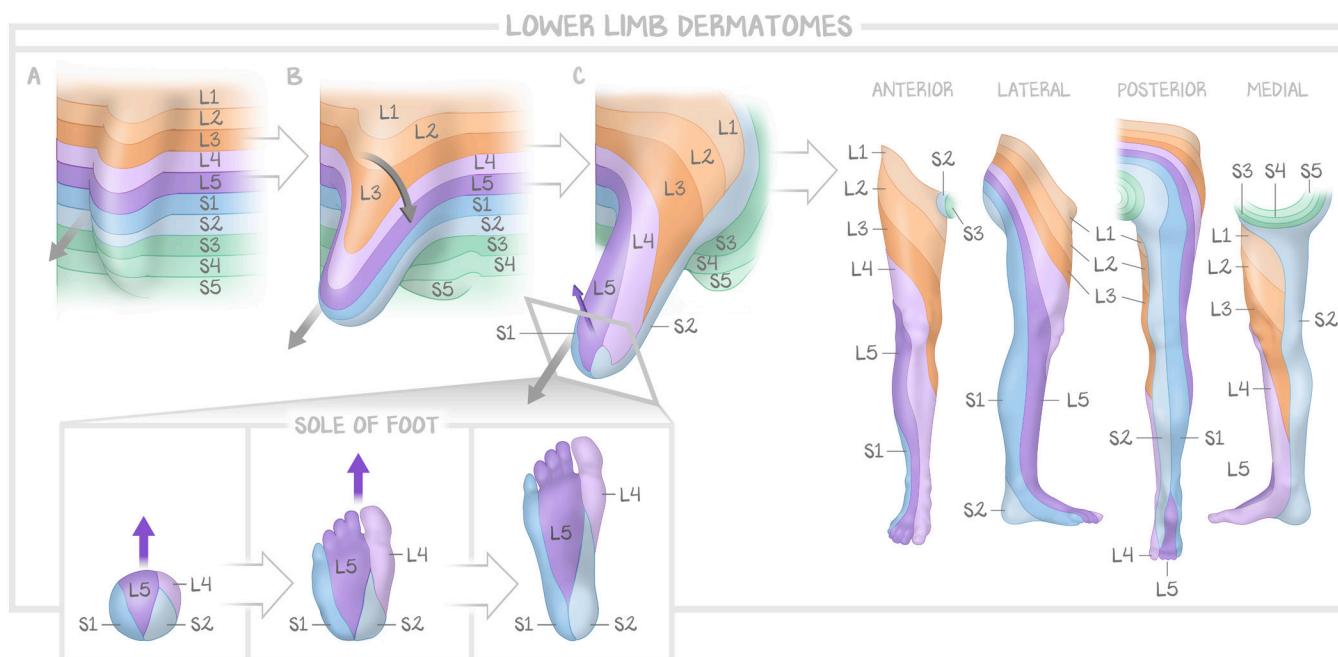
## Cutaneous Innervation

In the lesson on the upper extremity nerves we discussed dermatomes and terminal nerves. The thing is, with the upper extremity, there was a single plexus (the brachial plexus) and only a few nerve roots (C5–T1). There was also a simple pattern where the higher nerve roots innervated the lateral arm, moved down toward the middle finger, then came back up the medial arm. The lower extremity does something similar, but with a little twist. That “little twist” makes it really hard for many students to easily visualize the dermatomal distribution of the leg. The lower extremity is innervated by two plexuses—the lumbar plexus and the sacral plexus, which most people just refer to as the lumbosacral plexus. The lumbosacral plexus runs from L1–S5, twice as many nerve roots as in the upper extremity. And with so many nerve roots involved in innervation of the leg, you probably won’t be surprised there are many more terminal nerves in the lower extremity than in the upper extremity. So what does that mean for you?

First, **the twisty dermatome**. This next paragraph will attempt to explain the dermatomes of the leg. If you cannot visualize this, do not fret. The last section in this lesson covers **radiculopathies**, specific syndromes that involve specific nerve roots. Those syndromes are more important than being able to map a nerve to a dermatome. But here we go.

The most superior nerve roots (L1, L2) of the lumbosacral plexus innervate the medial thigh. In succession, the dermatomal distribution moves from the medial thigh, down on the anterior thigh, to the anterior shin. Right around S1 there is a wrap around the foot. The dorsum of the foot is innervated by S1; over the front of the toes and around the plantar surface and heel is S2. Then, ascending the posterior leg we continue the nerve roots, S3 posterior thigh, S4 gluteal, and S5 anus.

"The twist" can also be visualized by taking your left hand and placing it on your right medial thigh. Move your hand to your knee and down your shin. Run it over the top of your foot. Invert your foot, fold your hand over your toes and up the plantar aspect to the heel. Then run your hand up your calf and reach under you posterior thigh. You started at L1. You inverted your foot at S1. Your hand came to rest on the posterior thigh at S3.



**Figure 6.2: Dermatomes of the Lower Extremity**

The lower extremity dermatomal mapping is more complicated than the upper extremity. This visualization is intended for your mind to see the pattern, the 'rotating limb' during development as a means of making sense of the lower extremity map.

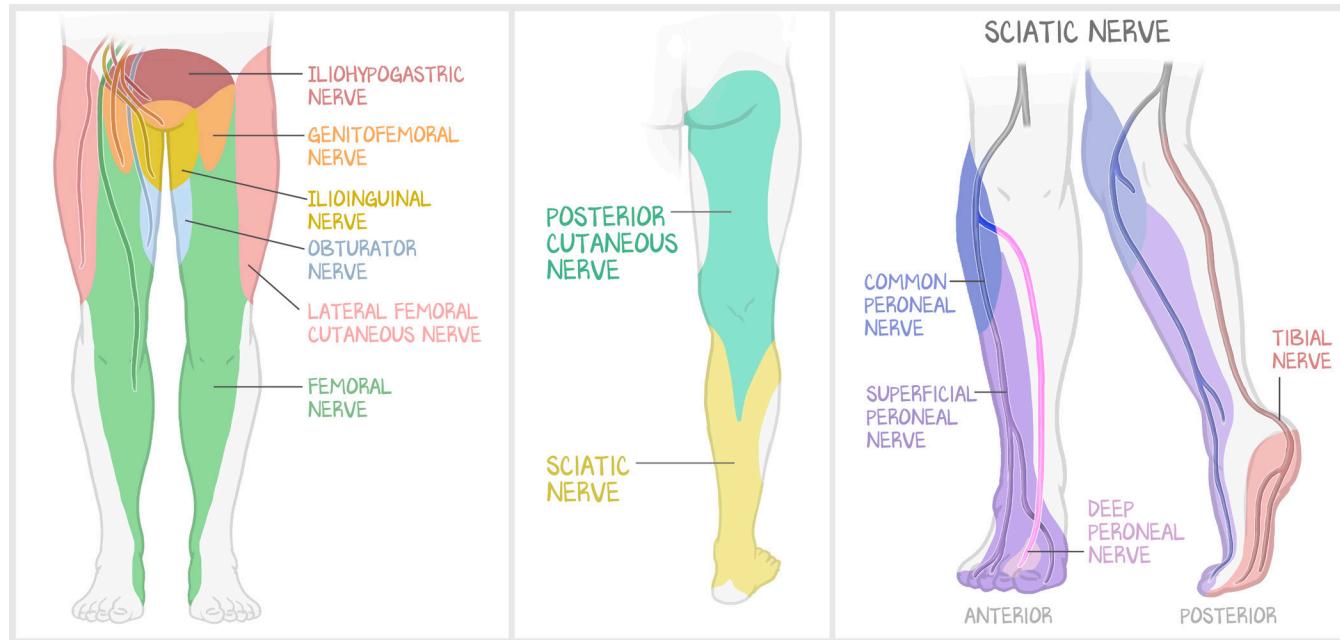
Second, a **clinical approach to terminal nerves**. Your task is not to surgically dissect the nerves nor know every innervation of every branch of the terminal nerves. Your task will be to either know the lesioned nerve and anticipate the physical exam findings, or, more often in clinical practice, know the physical exam findings and mechanism of injury and deduce which nerve is potentially lesioned. That means you can have three pieces of information—(1) how an injury occurred, (2) what the nerve is, and (3) what that nerve does.

The problem is that there are A LOT of terminal nerves in the lower extremity. To help reduce how daunting this content is, we are not going to teach you "the leg," but rather three distinct regions of the leg. These are not muscle compartments. These are going to be regions of the lower extremity that share nearby dermatomal innervation—the proximal nerves, distal nerves, and posterior nerves.

The **proximal nerves** are the iliohypogastric, genitofemoral, obturator, and lateral cutaneous femoral nerve. These four nerves originate from the most superior nerve roots of the lumbosacral plexus and innervate the medial and anterior thigh.

The **distal nerves** are the branches of the sciatic nerve—deep peroneal/fibular, superficial peroneal/fibular, and tibial. These nerves innervate the foreleg, starting with the anterior shin. They wrap around the toes, also innervate the heel.

The **posterior nerves** are the posterior cutaneous nerve of the thigh, the inferior gluteal nerve, the superior gluteal nerve, and the pudendal nerve. These nerves either do cutaneous innervation of the back of the leg or motor to the gluteal and adductor compartments.



**Figure 6.3: Sensory Innervation of the Lower Extremity**

We simplify the cutaneous innervation of the lower extremity by breaking up the terminal nerves into three regions—proximal, distal, and posterior. The anterior lower extremity is innervated by several different nerves from the lumbosacral plexus—iliohypogastric, genitofemoral, ilioinguinal, femoral and lateral femoral cutaneous nerves. The posterior of the lower extremity is easier—the posterior cutaneous nerve of the thigh and the sciatic nerve. What's left over—lateral foreleg and foot—is innervated by terminal branches of the sciatic nerve. We call that the distal nerves—lateral leg is superficial peroneal, the sole of the foot is tibial, and the web of skin between digits 1 and 2 is the deep peroneal nerve.

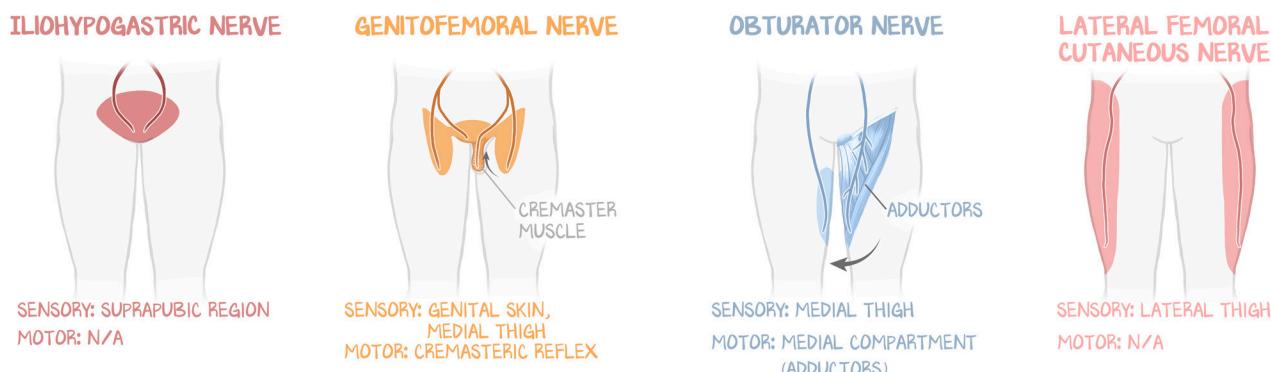
## Proximal Nerves and Their Lesions

The **iliohypogastric (T12–L1)** nerve is the highest terminal nerve, originating from nerve roots T12 and L1. It is so high up in the spine that it doesn't even innervate the leg at all. Instead, the iliohypogastric is the sensory nerve for the hypogastric region. Hypogastric is synonymous with suprapubic. It is cutaneous sensation over the pelvis and lower abdomen. There is **no motor**. Iliohypogastric nerves can be injured during the suturing closed of a transverse lower abdominal incision, classily associated with Caesarean sections and transabdominal hysterectomies. The transverse section is perpendicular to the axial skeleton and crosses where the iliohypogastric nerve can be. When suturing the wound closed, the nerve can be impinged by the suture. The patient will present with **paresthesias over the suprapubic skin** on the ipsilateral side.

The **genitofemoral (L1–L2)** nerve is next. The genitofemoral nerve innervates the **medial thigh** and scrotum/labia majora, as well as supplies motor innervation to the **cremasteric reflex**. This nerve can be injured during abdominal surgery if retractors are used to maintain a visual field. The compression of the nerve by the retractor leads to symptoms—the **loss of cremasteric reflex** and **medial thigh paresthesias**. The cremasteric reflex is contraction of the cremasteric muscle, lifting the ipsilateral testis towards the inguinal canal, when the inner thigh is stroked.

The **obturator nerve (L2–L4)** provides motor innervation to the medial compartment of the thigh (the adductors), where it travels through the obturator foramen, and innervates an obturator muscle. Its cutaneous innervation is a sliver of medial thigh. Loss of the obturator nerve can occur during **pelvic laparoscopic surgery**, where the placement of the trocar can penetrate the nerve. The patient will have weakness with adducting the femur.

The **lateral cutaneous femoral nerve (L2–L3)** is a cutaneous nerve only and has no motor innervation. It innervates the lateral thigh. It is a superficial nerve so it can be easily compressed from the outside. Compression occurs from wearing clothes that are too tight. This happens in **obesity** and in **pregnancy**, when clothes are not adjusted for increasing size. There will be the loss of sensation or paresthesias of the lateral thigh.



**Figure 6.4: Proximal Nerves**

Each of proximal nerves is highlighted individually. Some nerves have only sensory functions, some motor and sensory.

The **femoral nerve (also L2–L4)** is placed into our proximal nerve category. The thing is that it is huge and has many branches. Keep this as simple as possible. Do not learn the branches of the femoral nerve. The femoral nerve supplies the motor innervation to the **anterior compartment** (quadriceps) of the thigh. The femoral nerve supplies cutaneous sensory innervation to the **anteromedial thigh** (where the femoral nerve is called the proximal femoral nerve) and the **medial foreleg** (where the femoral nerve is called the sural nerve). Damage to the femoral nerve can occur in hip fractures or pelvic fractures. You should learn strictly that the loss of the femoral nerve will result in **loss of knee extension, loss of hip flexion, sensory loss of the thigh and medial foreleg**, and a **reduced knee jerk**.

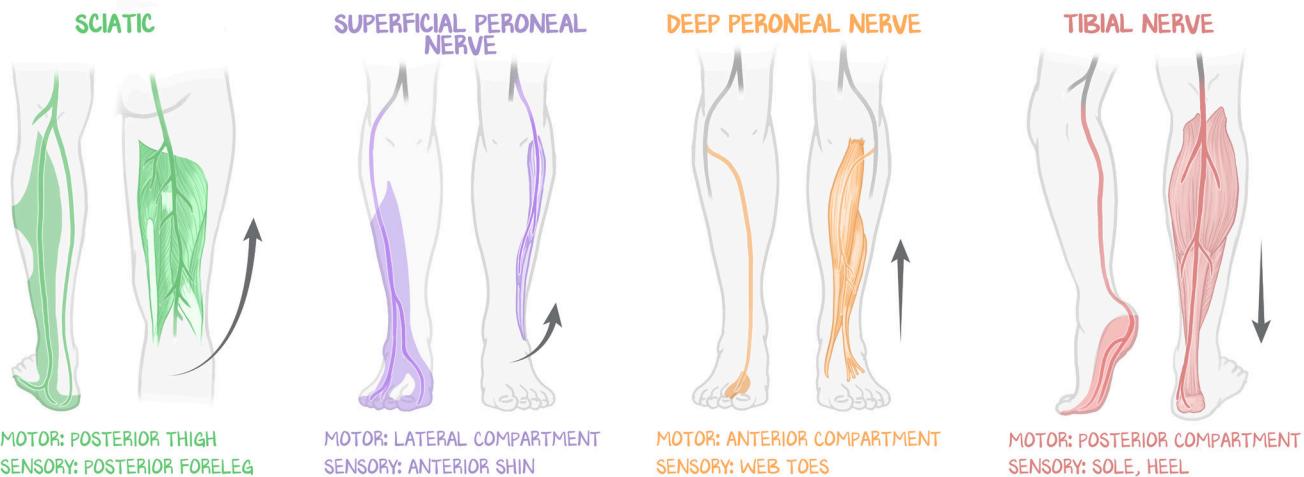
## Distal Nerves and Their Lesions

The **sciatic nerve (L4–S3)** is called the **proximal sciatic nerve** when it is in the thigh, has **no sensory innervation**, and is responsible for **posterior compartment motor innervation**. The sciatic nerve is called the distal sciatic nerve just before it trifurcates into three branches—the tibial nerve, the superficial peroneal/fibular nerve, and the deep peroneal/fibular nerve. Damage to the proximal sciatic nerve occurs with **posterior hip dislocations** and from **compression neuropathy** (the patient falls asleep on a toilet seat and compresses the nerve).

The **tibial nerve** is the posterior branch of the sciatic nerve and innervates the posterior compartment of the foreleg (plantarflexion and inversion). It is also responsible for sensation of the **heel of the foot**. Any lesion here will be easy to spot—loss of toe flexion, loss of plantarflexion, and **loss of sole of foot** sensation. Injury to the tibial nerve occurs with fracture of the tibia.

The **deep peroneal/fibular** nerve goes anterior, into the anterior compartment, where it innervates the muscles that perform dorsiflexion, toe extension, and inversion of the ankle. The sensory innervation is on the **lateral leg** and **dorsum of foot**, and **spares** the sensory between the big toe and the second digit. The deep fibular nerve is deep in the foreleg, so can be injured only by a fracture of the fibula.

The **superficial peroneal/fibular** nerve goes lateral, into the lateral compartment, where it innervates the fibular muscles that perform eversion. The deep sensory innervation is **absent except for that spot** the superficial missed. Because it is superficial, it can be easily compressed by leg casts or prolonged bedrest.



**Figure 6.5: Distal Nerves**

Each of distal nerves is highlighted individually. Nerves innervate muscle compartments and cutaneous sensation.

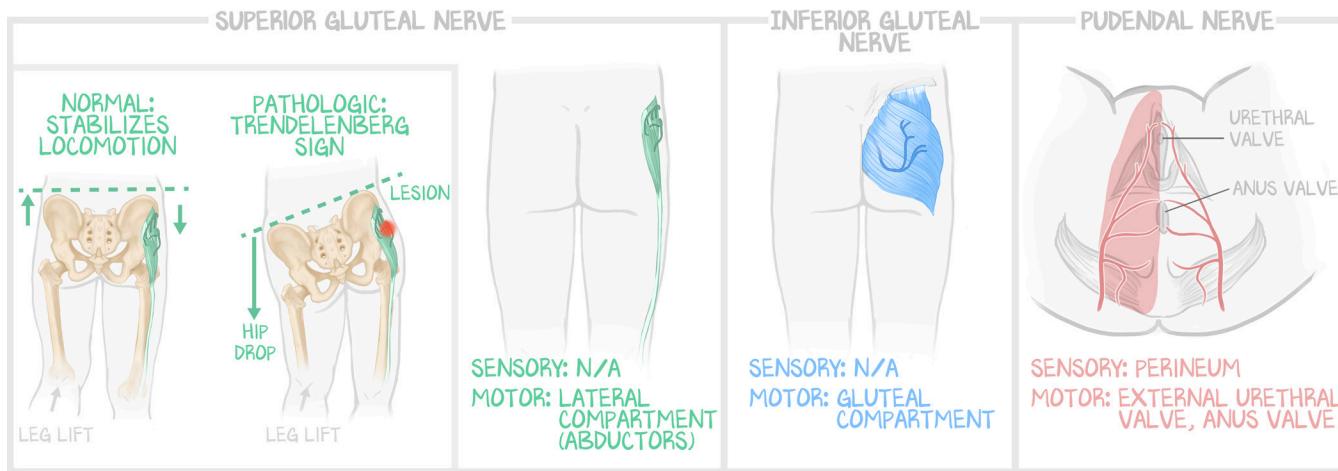
## Posterior Nerves and Their Lesions

The **posterior cutaneous nerve of the thigh** does sensation to the posterior thigh and buttocks. It has no motor innervation.

The **superior gluteal nerve (L4–S1)** innervates the *gluteus otherus* muscles, the abductor compartment. There is **no sensory** innervation. The abductors **stabilize the hip during locomotion**. Injury can be caused by erroneous injection of intramuscular medication into the superomedial quadrant, rather than the superolateral quadrant of the gluteus muscle. When this nerve is injured, the **affected side does not contract**; so when the affected side's foot is down, the affected side does not stabilize the pelvis. Think of both sides contracting at the same time, pulling the pelvis down equally. Now the affected side lets go. The affected side rises in the air. What a practitioner sees is a **pelvic dip** on the **unaffected side** when the unaffected side picks up the foot to walk.

The **inferior gluteal nerve (L5–S2)** innervates the *gluteus maximus*; there is no sensory innervation. This can be injured in posterior hip dislocations. The patient will have difficulty with hip extension, trying to climb stairs, or rising from a seated position.

The **pudendal nerve (S2–S4)** innervates sensory to the perineum; there is no motor innervation. This nerve is used for obstetric anesthesia. By locating the ischial spine, an anesthetist can approximate the location of the pudendal nerve. The intended effect is the loss of pain from contractions. The expected side effect is loss of sphincter tone, leading to bowel and bladder incontinence.

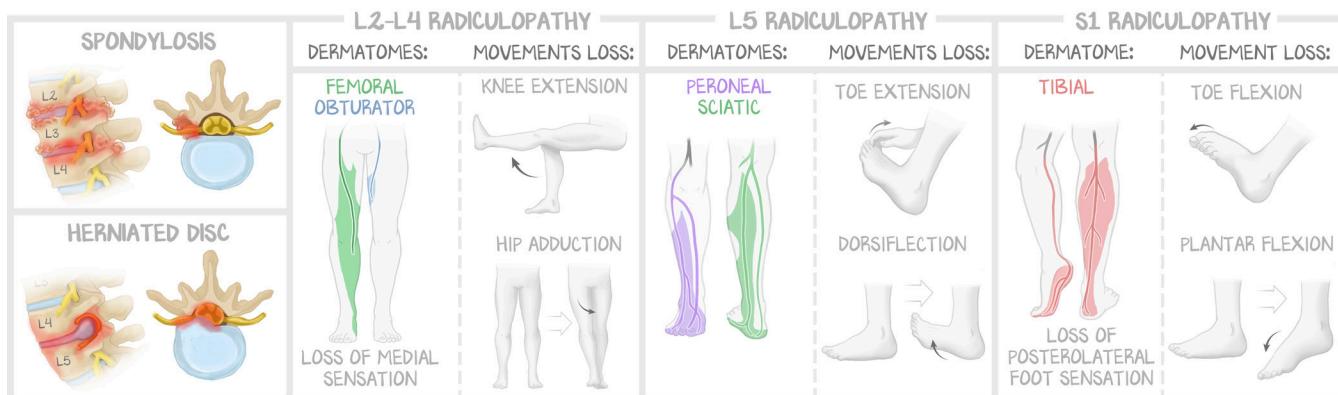
**Figure 6.6: Clinical Scenarios of the Sacral Plexus**

The posterior nerves don't fit into our categorization schema so well as they are mostly motor nerves (all except pudendal). The clinical scenarios therefore are more about weakness or motor dysfunction. During normal locomotion When a person lifts the left leg to walk, the hip extends and the knee flexes. This would shorten the left leg, tilting the pelvis down toward the left leg. The right leg is planted on the ground, and extends. Without any muscles to stabilize, the left pelvis would fall, which means the right pelvis would rise. The right abductors pull the pelvis against the femur that has a foot planted, pulling the right pelvis into place, preventing the rocking of the pelvis, keeping the pelvis level. In superior gluteal nerve injury, there is abnormal locomotion. When the right superior gluteal nerve is impaired, the right *gluteus medius* do not contract, and the right pelvis tips up as the left pelvis tips down. The patient feels the left pelvis tipping down when they walk. But because the pelvis is one bone, a left-tip-down is the same as a right-tip-up. An inferior gluteal nerve injury can occur if care is not made to inject in the right quadrant. The pudendal nerve has both motor to sphincters and sensory to the perineum.

## Lumbosacral Radiculopathy and Getting Test Questions Correct

This section is going to be about **lesions of the nerve root**. Nerve root injuries must, by definition, occur at the level of the spine, and since every peripheral nerve is a combination of multiple nerve roots, any one nerve root injury will impact the sensory and motor of multiple peripheral nerves.

Injury of the nerve root is caused by **acute disc herniation** (younger patients) or by **spondylosis** (older patients). Spondylosis is a general term that means “old-people changes in spine,” and can refer to disc degeneration, osteophytes, or calcifications.

**Figure 6.7: Nerve Root Lesions**

Nerve roots exit the vertebral column at the level of the vertebra. Between each vertebra is a disc. The L4/L5 disc is between L4 and L5. The nerve root of L4 has already exited the spinal column. The L5 nerve root exits below the L4/L5 disc. If the disc herniates, it will compress L5. By taking some sweeping liberties regarding anatomic accuracy, getting the answer—which nerve root is involved—can be massively simplified by mapping the nerve root radiculopathy onto a terminal nerve.

**L5 radiculopathy.** L5 radiculopathy is the most common radiculopathy and is caused by a herniation of the L4/L5 disc. There is **weakness in dorsiflexion**, toe extension, and both inversion (anterior compartment) and eversion (lateral compartment). There is either **pain or loss of sensation** of the **lateral shin and dorsum of foot**. If you see “cannot heel-walk,” the diagnosis is made.

**S1 radiculopathy.** S1 radiculopathy is the second most common radiculopathy and is caused by a herniation of the L5/S1 disc. The predominant features of S1 radiculopathy are the **weakness of plantarflexion** (the posterior compartment of the foreleg) pain or **loss of sensation of posterior and lateral foot**, and a **reduced ankle jerk**.

**L2-L4 radiculopathy.** L2-L4 is primarily the **femoral nerve** and the obturator nerve. The femoral nerve has anterior and lateral thigh sensation, as well as medial foreleg sensation. The obturator nerve has medial thigh sensation. The femoral nerve innervates the anterior thigh, and the obturator the medial thigh. You will not be asked to distinguish between L2, L3, and L4, and they all present similarly. These are higher up on the spinal cord, so are “higher up the leg,” involving problems with the knees and hips. **Weakness of knee extension**, impaired **hip adduction**, and loss of sensation of the **anterior thigh down to medial aspect of shin**. The key to identifying the femoral nerve, and therefore L2-L4, is the **absent knee jerk**.

NERVE	MUSCLE	SENSATION	INJURY	PRESENTATION
<b>PROXIMAL NERVES</b>				
Iliohypogastric T12-L1	Abdominal	Suprapubic	Transverse incision	Neuropathic pain
Genitofemoral L1-L2	Cremaster	Medial thigh, scrotum, labia majora	Abdominal surgery with retractor	Sensory loss over thigh, absent cremaster reflex
Obturator nerve L2-L4	Thigh Median compartment (adductors)	Medial thigh	Laparoscopic surgery	Loss of adduction Loss of sensation
Lateral cutaneous Femoral nerve L2-L3	None	Anterolateral thigh	Tight clothes, obesity, pregnancy	Sensory loss of the anterolateral thigh
Femoral nerve L2-L4	Thigh, anterior compartment (quadriceps)	Anteromedial thigh Medial leg	Hip fracture Pelvic fracture	Loss of hip flexion Loss of knee extension Reduced knee jerk Sensory loss

NERVE	MUSCLE	SENSATION	INJURY	PRESENTATION
<b>DISTAL NERVES</b>				
Proximal sciatic L4-S3	Thigh, posterior compartment (hamstrings)	None	Herniated disc Post hip dislocation Hip fracture	Loss of hamstrings But also: Loss of all motor in foreleg Lost ankle jerk
Superficial peroneal/fibular (from sciatic)	Lateral compartment Eversion of ankle	Lateral leg and dorsum foot, except the web between big toe and middle toe	Fibular neck fracture Compartment syndrome	Depending on level of injury, there will be a loss of common fibular function, or just the superficial or deep branches. “Steppage gait”
Deep peroneal/fibular (from sciatic)	Anterior compartment Dorsiflexion and inversion foot	The web btwn hallux and 2 <sup>nd</sup> digit (super high yield)		
Tibial (from sciatic)	Posterior compartment Plantarflexion and inversion	The rest of the sciatic nerve innervation	Knee trauma Tarsal tunnel Baker's cyst	Loss of sole sensation, toe flexion, and plantarflexion
<b>POSTERIOR</b>				
Posterior cutaneous nerve of the thigh				
Superior gluteal (L4-S1)	<i>Gluteus otherus</i> , abductor Internal rotation, stabilize locomotion	None	Iatrogenic injection injury in the wrong quadrant. Choose superolateral quadrant.	Positive Trendelenburg sign (affected side fails to contract, unaffected side dips)
Inferior gluteal (L5-S2)	Gluteus maximus Extension of hip	None	Posterior hip dislocation	Loss of hip extension (climbing stairs)
Pudendal (S2-S4)	Urethral and anal sphincters	Perineum	Childbirth, or intentional pudendal nerve block	Loss of perineal and genital sensation Loss of sphincter tone

**Table 6.2: Nerves of the Lower Extremity**